Fall 2020

Soil Degradation and Erosion

Anthany Ravanh
aravanh2@stu.parkland.edu

Soil Degradation

Anthany Ravanh
Fall 2020
CHE – 141 – 405H
Dr. Britt Carlson

What is Soil Degradation?

Soil degradation is a broad term referring to the general decline in a soil's physical and chemical properties such as:

- Decline in the physical structure
  - Water retention
  - Soil compaction
- Decline in organic matter
  - Microbes
- Decline in Fertility

(Photo of Dry Cracked Soil).

(Soil Degradation)

Soil Erosion and Degradation

(Photo of Water Runoff and Erosion on a Farm Field).

A major player in soil degradation is water erosion. Loose topsoil, due to poor vegetation and over-cultivation, is swept away by heavy rains or flooding. This leads to:

- Loss of soil for agriculture
- Less fertile soil
- Large amounts of runoff from fertilizers and pesticides in the topsoil

(Soil Degradation)

Soil Erosion and Degradation

(Dust Being Kicked up in a Crop Field).

Soil can also be eroded by the wind. Loose and uncovered dirt without trees or shrubs to protect them can easily be carried away by wind. Like water erosion, this strips the fertile top layer of soil away, but it also causes:

- Dust storms
  - Damages crops and infrastructure
- Health problems (like asthma)
- Harm to the environment

(Soil Degradation)

How does Agriculture Affect soil?

Conventional plowing methods are meant to break up poor, dense soil and better incorporate nutrients into the ground. This method turns the soil over to cover any residue (leftover organic matter from the last harvest) for more fertilization and kill weeds, reducing the need for herbicides.

A Moldboard plow (Smith).

(Why Do They Do That? - Plowing or Tilling Fields)

How does Agriculture Affect soil?

However, in breaking up the soil they damage its structure by removing sturdy roots that kept the soil in place and surface residue which covered the dirt from heavy rain and wind. Tilling also disturbs microorganisms inhabiting and benefiting the soil, reducing its fertility and stability.

(A No-till Field Covered With Residue).

(Tillage and No- Till Systems)

The Effect of Agriculture on a Soil's Physiological Profile.

Does plowing really cause that much damage?

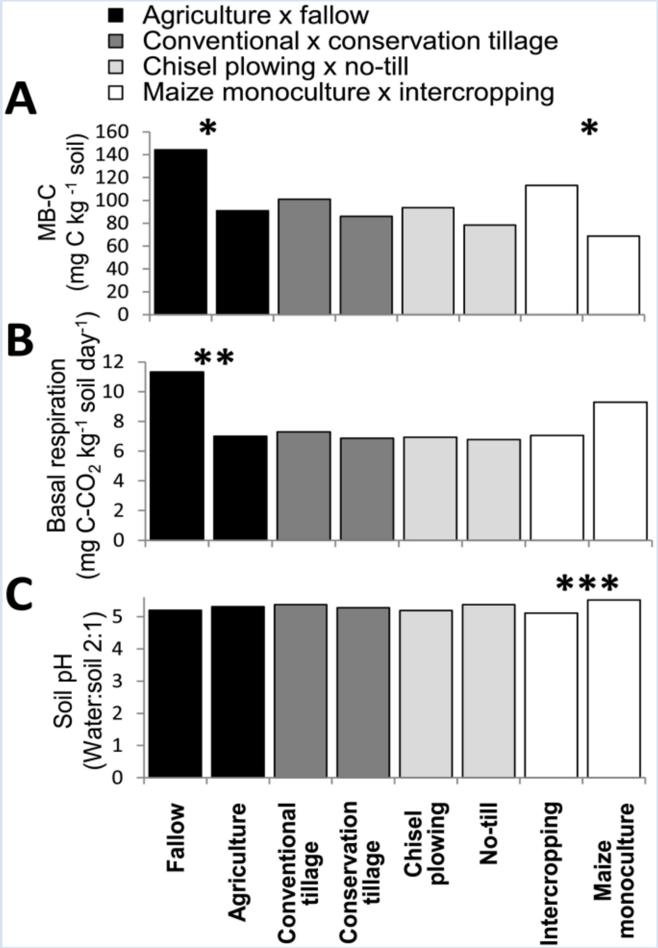
Starting in 2001, a group of Brazilian researchers investigated the impact of multiple agricultural practices on soil microbes and other properties. To do this, they set up multiple plots of land and managed each of them over nine years with a different combination of six agricultural practices :

- Conventional tilling
- Chisel Plowing (Conservational*)
- No-till (Conservational*)
- Intercropping
- Monocropping
- Fallow (completely untouched land)

*Conservational methods reduce or eliminates residue coverage from tilling.

(Lopez &Fernandes 1)

The Effect of Agriculture on a Soil's Physiological Profile.



In mid-2010, they sampled and tested each plot for a range of soil and microbe qualities (e.g., pH levels, biomass, and bacteria biomarkers). They found that, by a large margin, the **fallow fields** had higher quality soil and healthier microbes than any other sample.

The fallow field contained higher amounts of microbial biomass (chart A), a higher rate of decomposition (chart B), and stronger soil aggregates that resist erosion.

Effects of Different Agricultural Practices on Microbes (Lopes & Fernandes).

(Lopez &Fernandes 6)

The Effect of Agriculture on a Soil's Physiological Profile.

To explain this, the experimenters theorized that the abundance of different plants and, more specifically, their roots greatly benefitted the growth of microbes compared to the spaced-out crops in the rest of the fields. Agricultural fields, when monocropping, don’t have these advantages and were also treated with chemicals, all of which may contribute to the poorer, weaker soil microbes.

(Lopez &Fernandes 6)

Microorganisms' Role in Preventing Soil Erosion.

But Why Do Microbes Matter?

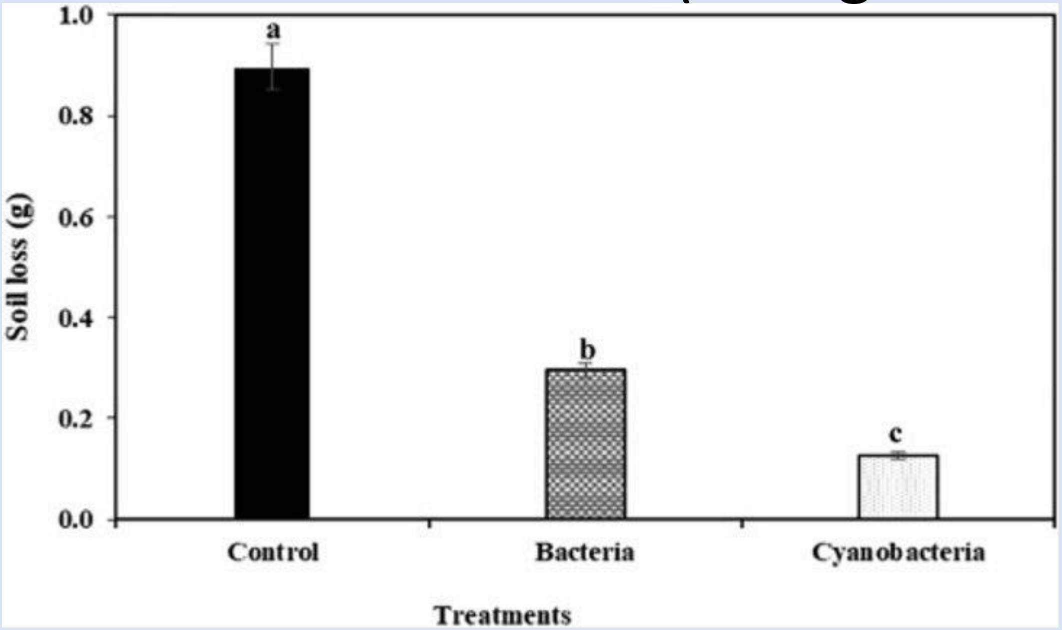
Another study, conducted by researchers Tarbiat Modares University in Iran, aimed to test the effect that bacteria and cyanobacteria against water erosion in soil affected by the freeze-thaw cycle, a cycle which accelerates soil erosion. They created a total of 18 small plots of soil (50cm at most on each side) to be tested, transferring bacteria and cyanobacteria to six plots each and leaving the last six as control.

(Sadeghi et al. 3)

Microorganisms' Role in Preventing Soil Erosion.

After freezing and thawing the samples in a freezer to weaken the soil, they were subjected to simulated rainfall in their Rainfall and Soil Erosion Simulation Laboratory and the amount of soil lost was recorded (Sadeghi et al. 3).

In the end, they found that the inclusion of bacteria reduced total erosion by **3.03 times** and cyanobacteria reduced it by **7.07 times** (Sadeghi et al. 4). The microorganisms also significantly lowered the maximum rate of soil erosion and extended the time it took to get to that point(Sadeghi et al. 4).



Graph of Total Soil Losses (Sadeghi et al).

Microorganisms' Role in Preventing Soil Erosion.

They concluded that these microbes drastically reduced soil erosion, likely by producing adhesive chemicals to hold the soil together and forming a biological crust on the surface (Sadeghi et al. 5).

This layer of bounded soil and microbes shielded the ground beneath it from wind and raindrops (Sadeghi et al. 4). It is integral to the stability of the soil and without it the soil is severely compromised.

Biocrust on the surface of the soil (Sadeghet al).

Further Research

These two studies work together to show how conventional methods of agriculture can undermine soil quality, especially when it comes to erosion. They also give some potential solutions to these problems.

- By comparing tilling systems, Lopes presents potential alternatives to conventional plowing which, although not as effective as not farming at all, still produces better soil for farming and to deal with erosion (Lopes and Fernandes 7).
- At the same time, the results from Sadeghi's and his team's experiment suggests that implanting bacteria could be viable as an affordable defense against the weather (Sadeghi et al. 8).

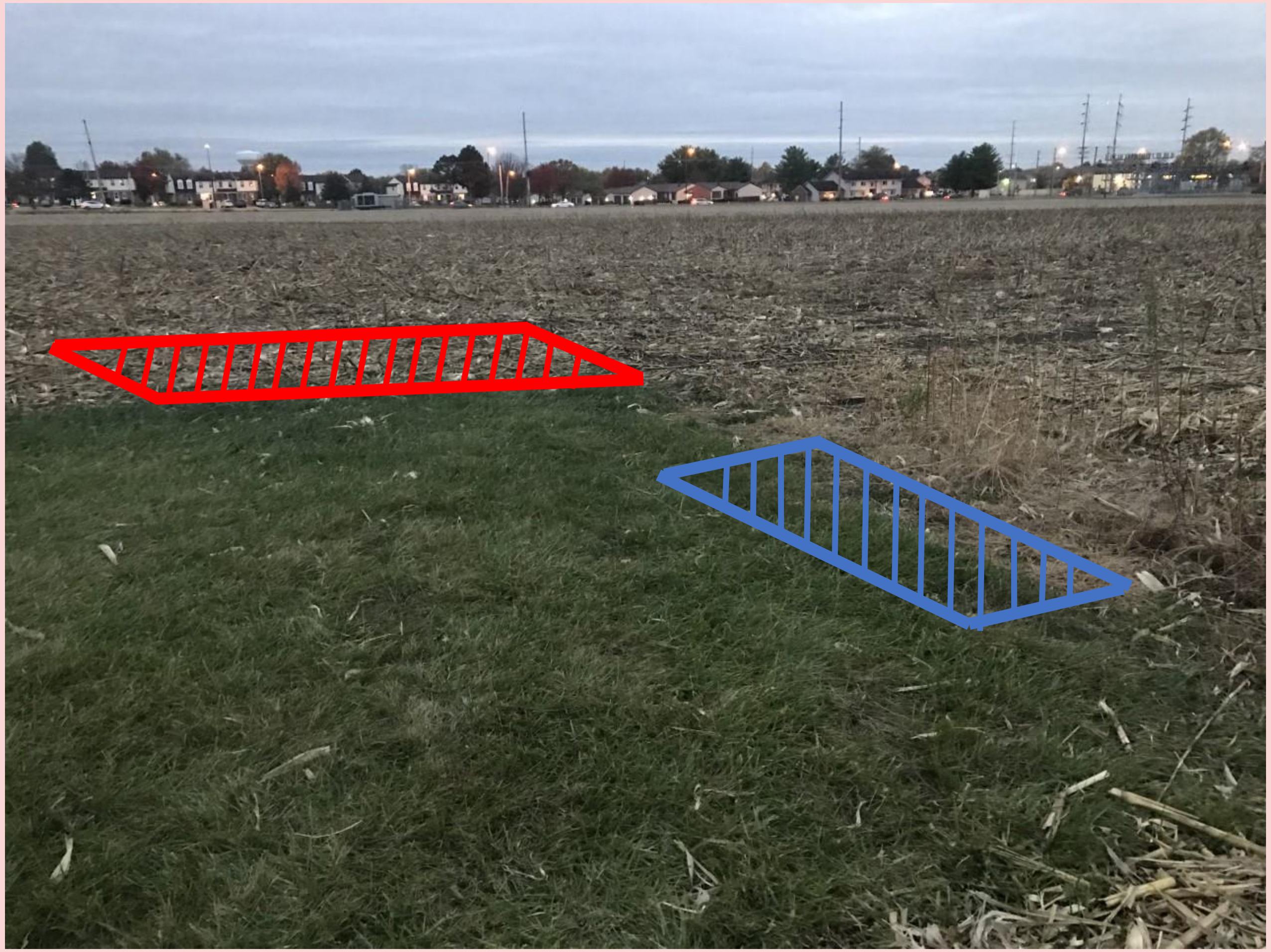
Yet, neither article is perfect and both prompt further research into the long-term relationship between microorganisms and other soil properties besides erosion.

My Own Experiential Research:

I wanted to see if I could replicate some of these findings by myself, so I chose to compare farmed soil inside the cornfield to soil from the lawn by the outside edges of the field.

I wanted to see the effects that agricultural practices would have on soil quality and, based on my research, I expected the soil from inside the field to have fewer microbes, be less stable and be less healthy overall than the soil from outside of the field because of these practices.

Soil Sampling:



General areas sampled for the lab. The photo was not taken on the same day as the lab, hence the empty field.

Using shovels and a sampling tool, I gathered a quart of soil from each area I wanted to investigate, sampling at a depth of up to 30cm deep while recording observations.

- The soil from inside the field appeared to be far more baren on the surface and dry.
- The soil from the outside edge of the field was less brittle and far moister than the other sample.

Source of soil from **OUTSIDE** the field

Source of soil from **INSIDE** the field

XRF and FT-IR Spectroscopy:

After sieving my samples into three size categories each (>6mm, 6mm>x>2mm, and <2mm) and grinding the <2mm soils for 6 total bags of soil, we investigated the elemental and chemical composition of the <2mm soils at Turner Hall on UIUC campus. Using the portable XRF machine, we found part of the compositions of our soils while specifically focusing on the levels of Pb (lead):

Element:	PPM:
Cr	43 (+/-20)
Ni	25 (+/-8)
Pb	17 (+/-11)
Zr	326 (+/-9)
Zn	64 (+/-8)

Inside of the Field

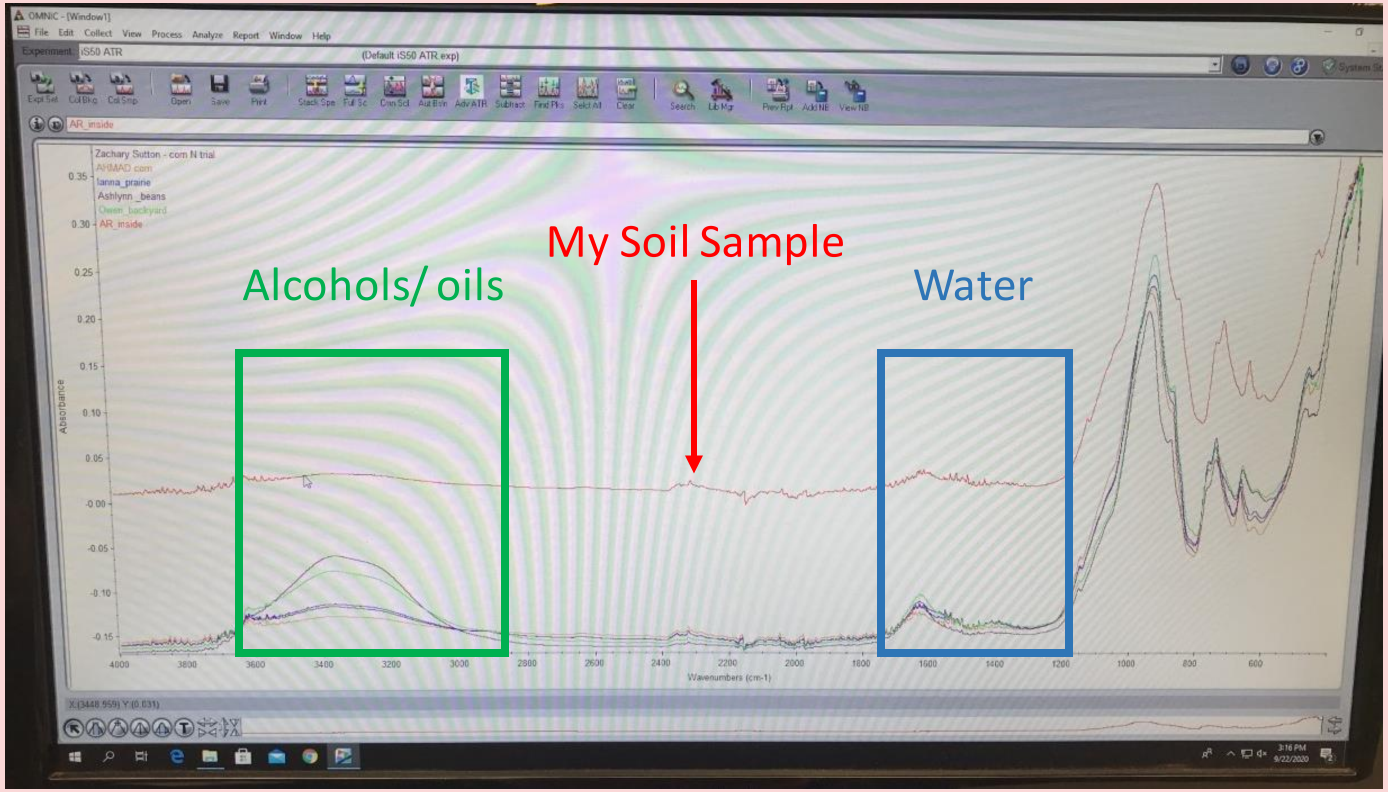
There were safe levels of Pb in both samples (both under 400 PPM) and the compositions of the two soils are very similar, with most of the elements being within a margin of error of each other. This was expected since both soils were sampled close to each other.

Element:	PPM:
Cr	54 (+/-23)
Ni	20 (+/-8)
Pb	29 (+/-22)
Zr	356 (+/-9)
Zn	70 (+/-8)

Outside Edge of the Field

XRF and FT-IR Spectroscopy:

Afterward, using an Infrared Spectroscopy machine, we found the types of bonds in our soils. Looking at the result for the soil from inside the field, we can see that there is a distinct lack of alcohols/ oils (which is related to organic matter) and a smaller amount of water in the soil than most other samples.



Graph of the FT-IR readings of the <2mm ground soil from inside the field. My soil sample, graphed in red, was shifted upwards to help with visibility, so my results should be **lower** than most of the other results.

Soil Texture:

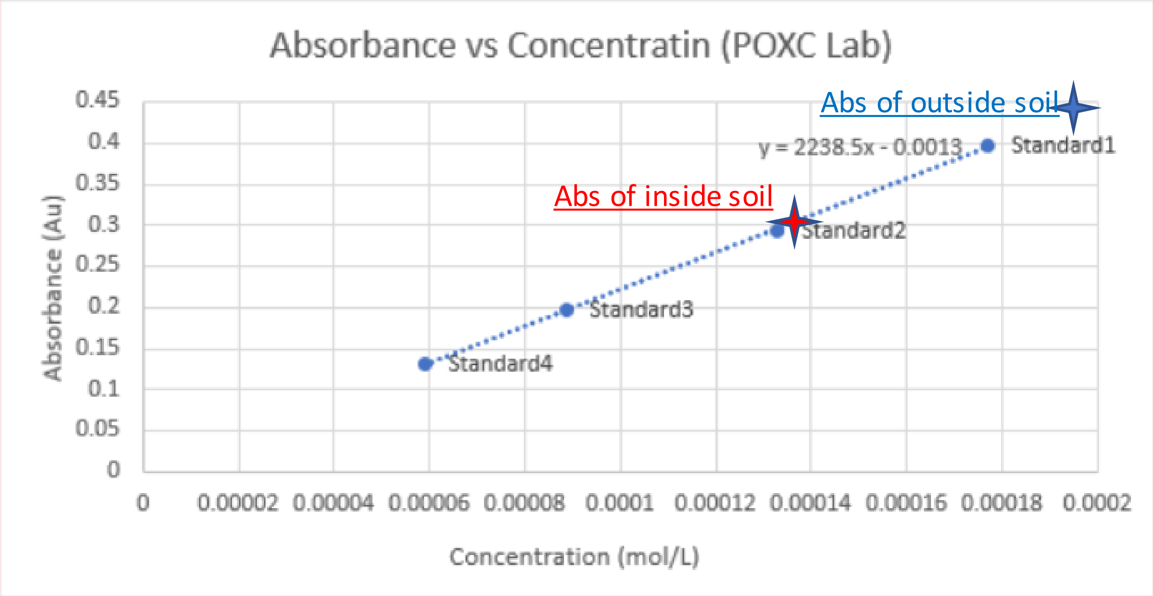
Next, I calculated the soil textures for both soils breaking up the soils using H_2O_2, placing them into water, and using a hydrometer to measure their densities after mixing and setting. I then calculated the % composition of each soil and used it to help determine their soil types. In the end, both were classified as **clay loam**.

Types:	Inside the Field:	Outside the Field:
% Silt	29.9%	29.2%
% Clay	33.3%	33.7%
% Sand	36.8%	37.1%

Their % compositions (shown above) were extremely similar, telling us that any differences between the soils will likely be because of different land management and not because they were different types of soil.

POXC Labs:

I then found the amount of carbon in each of the soils by reacting some of the carbon in the <2mm grounded samples with an indicator and seeing how much of it was reacted using a spectrophotometer. With the absorbance of each sample, I used the graph below (made from the standards that we produced) to find the concentration of reactant left in the sample and the amount of reactive carbon (RC) that was present in each of our soils.



The soil from inside the field had **440** $\frac{mg\ RC}{kg}$, while the soil from outside the field had **350** $\frac{mg\ RC}{kg}$, likely meaning the soil in the field had more carbon and therefore more life than the other sample.

Graph of Absorbance versus Concentration of $KMnO_4$ standards used for calculation. The higher the absorbance, the more $KMnO_4$ was left unreacted and the less RC was in the sample.

Microbial Activity Titration:

To get a sense of how much life was in the soils, by isolating the samples in separate jars with a base, “trapping” some of the CO_2 they produce, and titrating the trapped CO_2 with HCl, I found out how much CO_2 was produced by active organisms and microbes in the soil.

After some calculations, I found that the soil from inside the field produced **67.0mg** of $\frac{CO_2}{kg*day}$ while the soil from outside the field produced **103mg** of $\frac{CO_2}{kg*day}$.

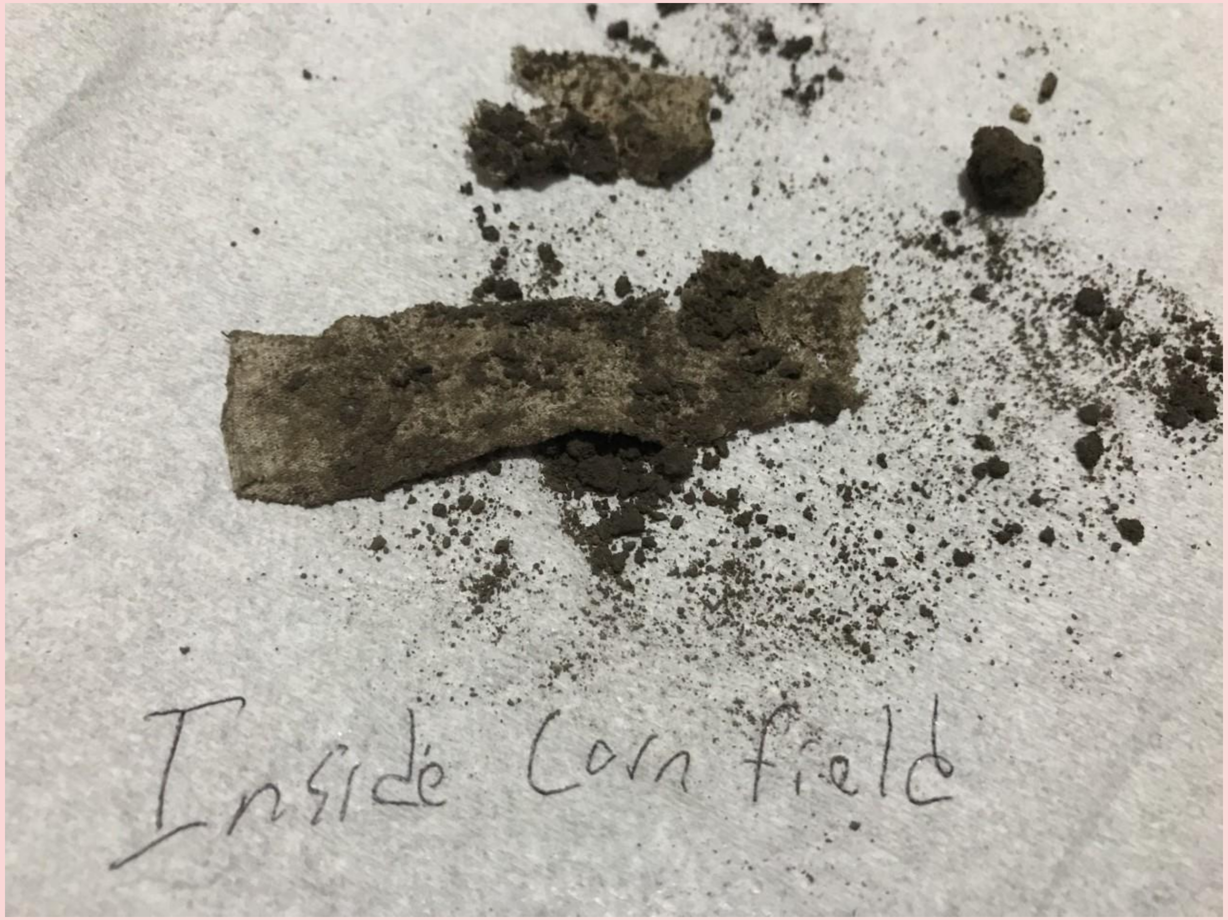
This seems to contradict the POXC lab results and could mean that, although there is more carbon inside the cornfield, there is more microbial life in the soil outside of it.

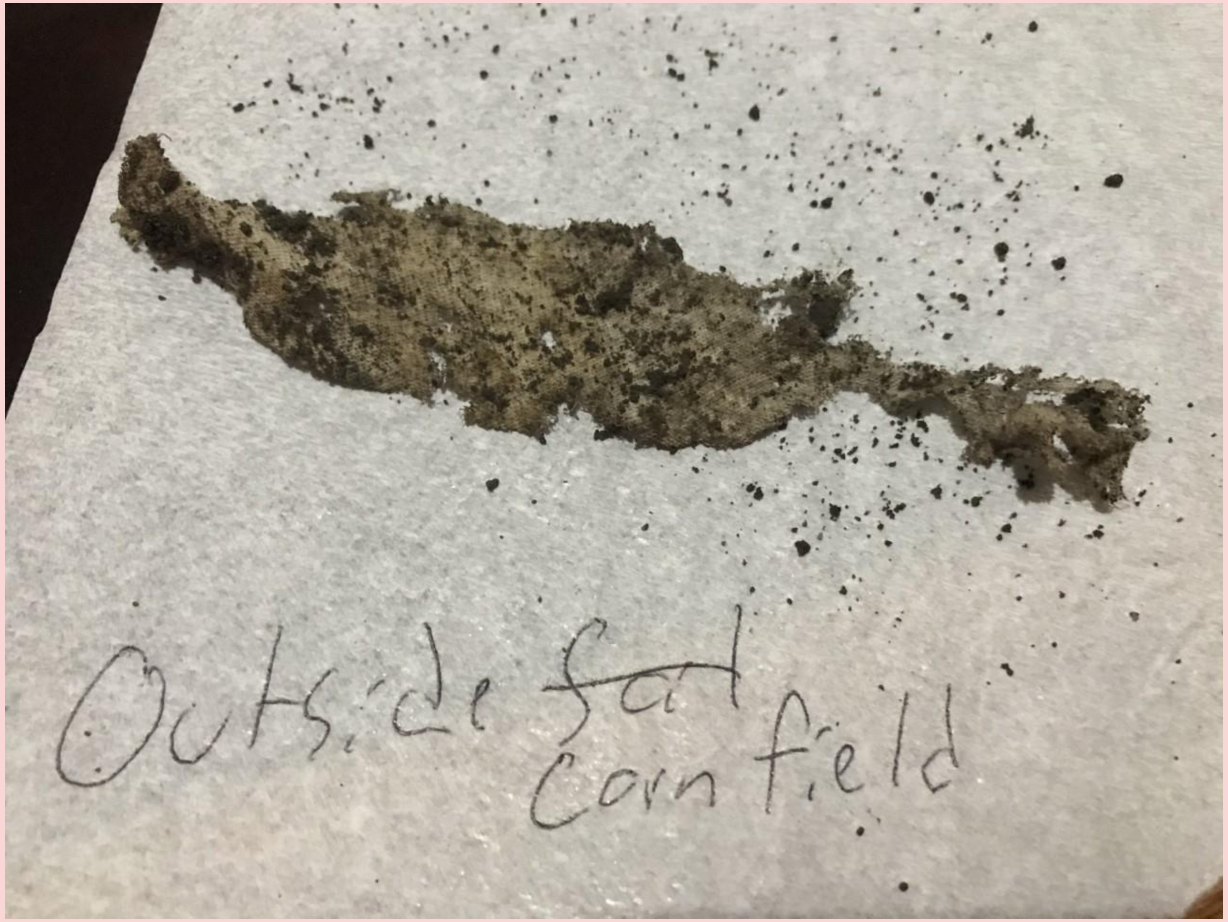
The Cotton Test:

The Cotton Test also tested for active microbes in the soil, but by leaving a strip of cotton in two separate bags of fresh soil from each sample for two months and comparing the rates of decomposition.

After two months, from September 8 (right after sampling) to November 10, both bags were carefully opened to examine the cotton. Although the cotton from the soil inside the field was split in two and discolored, the cotton from the soil outside of the field was far more decomposed and tattered, meaning the soil outside of the field had more microbial activity. This is supported by the fact that it also tore far easier compared to the cotton from the soil inside the field.

The Cotton Test (Results):





Remains of the cotton strips. Cotton from soil inside the field is left and outside the field is right. Notice how, despite splitting into two pieces, the cotton on the left remains rectangular while the other does not.

Conductivity, pH and Slake Tests:

The final tests I did measured the soils' pH, conductivity, and stability. We measured the pH and conductivity by simply measuring it with a device while submerged in water.

Test:	Inside the Field:	Outside the Field:
pH:	5.44 pH	5.74 pH
Conductivity:	198.0 µS	146.8 µS

Both samples were very acidic, being under the average pH range of 6.5 to 7.5, so since the soil outside of the field is closer to a healthy pH, it probably better supports plant life. On the other hand, the soil from inside the field has a higher conductivity than the other soil so it theoretically contained more nutrients.

Lastly, during the slake test we placed a ped of soil onto a mesh above some water and observed as it slowly sucked up water and crumbled. Interestingly, although the ped from inside the field held its shape better, thus being more stable, the soil from outside of the field absorbed the water far faster and had larger soil aggregates.

Conclusion:

If we take the results at face value, they show that my hypothesis was incorrect and neither soil was overwhelmingly healthier than the other, despite what my online research suggests.

- On one hand, the results from the FT-IR lab, the Microbial Activity Titration lab, and the Cotton Test suggest that the soil taken from outside has more active microbes and holds more water than the soil from inside the field, all signs of healthier soil.
- However, the POXC labs, Conductivity test, and Slake test showed that the soil from inside the field has more carbon (a sign of more organic matter, alive or dead), potentially has more nutrients and is more erosion resistant.

Although the soil from outside the field had more signs of life, the soil from inside the field generally has more biomass and other soil qualities that should make it better for supporting microbes.

Conclusion:

Overall, the farmed soil has not degraded as much as I initially believed it would and it only lacks active microbes when compared with non-farmed soil. It even appears that, in areas such as resistance to erosion, the farmed soil from inside the field was healthier. These results show that agricultural practices only disturbs the active microbes in the soil while potentially improving abiotic factors and other soil properties.

The Soil Texture lab and XFR test confirmed that these soils are of the same soil type and that their compositions are nearly identical to each other, so farming alone should be what has led to these differences.

Comparing Results:

To try and confirm these findings, I compared my data with some results from other students' experiments. As seen below, the pH, conductivity, and amount of CO_2 gas produced by my samples were average for the class.

However, the amount of RC in my soil (my POXC results) appears to be an ***order of magnitude*** lower than what some others found in theirs. Although this discrepancy could be because of the small amount of data from the class to compare with and errors in their work, it still casts doubt on the accuracy of my POXC and FT-IR labs.

pH (pH)	Conductivity (µS)	POXC $(\frac{\text{mg RC}}{\text{kg}})$	Microbial Activity CO_2 $(\frac{CO_2}{kg*day})$
6.63	287	71,208	300
6.23	206	4,071	**103**
5.74	**198**	1,108	**67**
5.44	**147**	**440**	55
5.41	145	**350**	**Not Enough Data**
5.30	105	152	

A table comparing the results of my experiments on the soil from **inside** and **outside** the cornfield to other student's data on the same type of soil. Note that the POXC lab involved a lot of math which could result in drastic differences from minor errors.

Errors:

My experiments were also riddled with errors that might have skewed the results. Some of them include:

- Sampling soil too close to the field when sampling for the "outside soil." The soil could have been affected by farming practices, making it a bad control variable.
- Only doing the FT-IR spectroscopy on one sample, so I could only compare the results from my test with that of the class rather than with the other soil sample. This is important if there was an issue in both of my samples that affected the results.
- Ending the Soil Texture lab an hour early before all the soil particles finished setting (although it probably is not a coincidence that the two samples were so similar).
- Failing multiple times at pipetting in all tests, resulting in slight differences in solution concentrations for the POXC and Microbial Titration labs.
- Dropping soil into the beaker containing the NaOH used as a CO_2 trap for my outside soil during the Microbial Activity Titration, making it seem like there is more carbon in the soil than there really was.

Errors:

The last and possibly largest error I made was leaving my soil samples out in broad daylight for over two weeks. Exposing the soil to sunlight could have killed off some of the microbes living in both soils unequally since one (possibly the outside soil) could have laid on top of another.

- This would also explain the extremely low levels of organic material shown by most of my labs *except* the Cotton lab, which was done with fresh soil, and the flawed Microbial Activity Titration lab.
- However, this is only a hypothesis and, other than coincidental evidence and being explicitly told not to do it, I have no evidence that that is what has happened.

Further Research:

Due to the large amount of problems in all my labs as well as the issue with the sunlight, re-doing all the tests with new soil samples that are stored properly is necessary. Doing the labs once already should make it easier to avoid most of these issues when testing the samples again, so these new results should be more reliable.

- If the labs are redone and similar results are reached, further research into the farming methods that Parkland uses would be important in understanding why this soil contradicts conventional research.
- If the new labs produce "normal" results with more biomass, the question of what caused the abnormally low carbon levels should also be investigated. Was it the exposure to sunlight that caused it, or was it something else entirely? Was it an error in my labs, or had I sampled a strange patch of soil?

Works Cited

A No-till Field Covered With Residue. Iowa Agriculture Literacy, 27 Aug. 2015, iowaagliteracy.wordpress.com/2015/04/27/why-do-they-do-that-plowing-or-tilling-fields/. Accessed 12 October 2020.

Dust Being Kicked up in Crop Field. Agriculture Victoria, State of Victoria, vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/lwm_land_deg_soil-erosion_wind-erosion. Accessed 10 October 2020.

Lopes, Lucas Dantas, and Marcelo Ferreira Fernandes. “Changes in Microbial Community Structure and Physiological Profile in a Kaolinitic Tropical Soil under Different Conservation Agricultural Practices.” *Applied Soil Ecology*, vol. 152, 2020, doi:10.1016/j.apsoil.2020.103545. Accessed 25 Feb. 2020.

"Minecraft Dirt Block." Pattern Crew, pva.supply/product/minecraft-dirt-block/. Accessed 11 November 2020.

"Minecraft Png." Pintrest, www.pinterest.com/pin/479211216582862098/. Accessed 23 November 2020.

Works Cited

Photo of Dry Cracked Soil. Pxfuel p1.pxfuel.com/preview/88/828/15/crack-land-drought-soil.jpg Accessed 9 October 2020

Photo of Water Runoff and Erosion on a Farm Field. Latham Seeds, 06 April 2020, www.lathamseeds.com/2020/01/managing-soil-erosion/h. Accessed 10 October 2020.

Sadeghi, Seyed Hamidreza, et al. “Reduction in Soil Loss Caused by a Freeze-Thaw Cycle through Inoculation of Endemic Soil Microorganisms.” *Applied Soil Ecology*, vol. 157, 2021, doi:10.1016/j.apsoil.2020.103770. Accessed 6 Oct. 2020.

Smith, Darrell. "Moldboard Plow." Ag Web, 04 October 2017, www.agweb.com/article/your-tillage-road-map--NAA-darrell-smith. Accessed 10 October 2020.

“Soil Degradation.” *NSW Environment, Energy and Science*, Department of Planning, Industry and Environment, 25 July 2019, www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation.

Works Cited

Sulaeman, Dede, and Thomas Westhoff. “The Causes and Effects of Soil Erosion, and How to Prevent It.” *World Resources Institute*, 7 Feb. 2020, www.wri.org/blog/2020/01/causes-effects-how-to-prevent-soil-erosion.

“Tillage and No-Till Systems.” *CropWatch*, University of Nebraska-Lincon, 20 Feb. 2020, cropwatch.unl.edu/tillage.

“Why Do They Do That? – Plowing or Tilling Fields.” *Iowa Agriculture Literacy*, 27 Aug. 2015, iowaagliteracy.wordpress.com/2015/04/27/why-do-they-do-that-plowing-or-tilling-fields/.